GARRISON

Illuminating Engineering in

Connection with Central Station Work

Electrical Engineer

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ILLUMINATING ENGINEERING

IN

CONNECTION WITH CENTRAL STATION WORK

BY

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ILLUMINATING ENGINEERING
IN
CONNECTION WITH CENTRAL STATION WORK

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The growth of the electrical industry along every line during the last two decades has been nothing short of marvelous, but that made by the central station has probably been the most important, because of the very large number of people who have been made dependent upon its product. Today the energy furnished by the central station is delivered to millions of customers who use it in innumerable ways conducive to comfort and convenience; among all these uses, the one which overshadows all others as regards universal application, the number of people affected, and the energy used, is the use of electricity for lighting.

For many years there was very little improvement in electrical illuminants; it is true the nernst and arc lamps of various styles were produced for lighting large interiors, but for smaller installations the universal practice was to suspend a carbon lamp, either with or without some sort shade, near the objects to be illuminated. For general lighting the cost of operating carbon lamps was almost prohibitive. During the last few years, however, the introduction of metal filament lamps has revolutionized the old methods of lighting. At first there was a general expression of fear by the central station people that these lamps would mean a very serious decrease in revenue, but the more progressive were quick to see,rather, an opportunity for expansion and an increase of lighting standards which would more than overbalance any temporary loss. To secure the greatest benefit from the oppor-

tunity it became necessary to make a thorough scientific study of the subject of lighting; this has lead to the employment by many central station companies of engineers, familiar with the basic principles of correct lighting, who devote their time to the study and application of these principles.

The work of the illuminating engineer is a mixture of the engineering and commercial; he must be thoroughly familiar with the application of engineering principles and at the same time be able to convince his customer that what recommends is best for the case under consideration. Of the two, to a competent engineer, the latter is far more difficult than the former. To one experienced in his work a brief inspection will oftentimes suffice to indicate the wattage and arrangement required to give satisfactory lighting conditions, but it is an altogether different proposition to fit a proper installation to the customer's sense of the esthetic, or more often to his pocketbook.

One of the most difficult things with which the engineer must contend in his fight to improve lighting conditions is the bigotry and narrow-mindedness of the average man. A great many people are satisfied with the old way and want no other; others are a little more progressive but are not sufficiently farsighted to see the returns which may be secured from a well designed lighting installation; still others are willing to make changes but are unable to appreciate quality and therefore greatly injure their own interests by the use of cheap material. There is always, however, a class in every community which is progressive and which is willing to lead the way. These people by their influence and example aid the illuminating engineer very much in his efforts among the less pro-

gressive classes.

It is therefore necessary to consider the personality of the customer in laying out an installation, although the proper design is best, even if it is certain not to be accepted in this form. By discarding or changing various elements after the design is brought to the attention of the customer it is often possible to secure a fairly good installation, but if an attempt is made to estimate the customer's choice previous to making the design, details may be omitted which might easily be included, and which, if omitted, would reduce materially the quality of the installation. The above statement, however, is not intended to convey the meaning that the customer should not be sounded before the design is made. His ideas should be obtained but if they conflict too much with what is very evidently for his best interest, the latter should be considered before the former. Every effort should then be made to install according to design, for any deviation therefrom is an injury to the customer and a poor installation does more harm than good.

As a result of efforts along these lines the standards of illumination are being constantly raised. Older methods of hanging bare lamps low and of making no provision for general illumination have been forced out. The very fragility of tungsten lamps, considered a detriment, has proven a blessing in disguise in that it has necessitated the raising of lighting units. This in turn has served to increase the general illumination and to develop a line of reflectors which re-direct and diffuse the light in a way more satisfactory than any heretofore put into use. Chief among the reflectors used for general illumination is the line manufactured by the Holophane Co.. These reflectors have in a measure be-

come standardized in three types, called from their distribution curves, extensive, intensive, and focusing. The selection of reflectors for any given installation is governed by the ratio of the height, h, above the plane of illumination, to the distance, d, of the lighting units apart, and is for the three types,

Type	h/d
E	.5
I	.8
F	I.4

These reflectors give a white,satiny light very pleasing to the eye and their appearance adapts them to the most artistic surroundings, while their usefulness renders them desirable where artistic effect is unnecessary.

In designing a general lighting installation the first step is to determine the wattage necessary to furnish the illumination desired. If the value of foot candles is selected from the table following, this is accomplished very satisfactorily by the use of the formula

$$\text{Watts} = \frac{\text{Area X Candle Feet}}{\text{Constant}}$$

given by Mr. J.R. Cravath for use with holophane reflectors. In this formula the constant varies from 3.5 to 5.0, depending upon the color of the walls With the wattage determined, the selection of the fixture and wattage per outlet determines the type of reflector. It is rarely necessary to use the point to point method in determining illumination as this is very little more accurate than the formula given; if this method is desirable, however, trade bulletins give tables

which render the work easy. Values of illumination common in various classes of lighting are given in the table following, taken from the bulletins of the National Electric Lamp Association. These values are, of course, in the nature of limits and the engineer must use his judgement in selecting.

Common Values of Illumination.

Auditoriums, theatres	1.0 - 3.0
Bookkeeping	3.0 - 5.0
Corridors, halls	.5 - 1.0
Depots, assembly halls, churches	.75- 1.5
Drafting rooms	5.0 -10.0
Desk lighting	2.0 - 5.0
Engraving	5.0 -10.0
Factories, general, individual drops	2.0 - 3.0
" , complete, no individual drops	4.0 - 5.0
Hotel halls	1.0 - 1.5
" rooms	2.0 - 3.0
Offices, waiting rooms	1.25- 2.5
" , private	2.0 - 3.0
" , general	3.0 - 4.0
Post offices	2.0 - 5.0
Reading	1.0 - 3.0
Residences	1.0 - 3.0
Stores, light goods	2.0 - 3.5
" , dry goods	4.0 - 6.0
" ,clothing	4.0 - 7.0
Store windows	5.0 -20.0
School rooms	2.0 - 3.0

Saloons, cafes, depending on effects	2.0 - 5.0
Stations, waiting rooms	I.5 - 2.5
Train sheds	1.5 - 2.0
Warehouses	I.5 - 2.0

For use with the point to point method the following table is given, showing the increase of illumination due to reflection.

Ceiling	Walls	% Increase over Value Calculated.
Very dark	Very dark	0%
Medium	" "	I5
"	Medium	40
Very light	Very dark	30
" "	Medium	55
" "	Very light	80

A formula for the rapid calculation of general illumination given in these bulletins is as follows;

$$\text{No. Lamps} = \frac{\text{Area X Candle Feet}}{\text{Effective Lumens per Lamp}}$$

The following table gives values for use in the formula.

Watts per Lamp	Effective Lumens per Lamp	Effective Lumens per Watt
25	95	3.8
40	160	4.0
60	250	4.2
I00	420	4.2
I50	630	4.2
250	I090	4.3

The distinction between the number of lumens per watt is unnecessary as the error due to reflection is greater than this difference The statement is made that for very light walls the number of effective lumens per lamp can be increased 25%. This gives limitng values of the effective lumens per watt of 3.8 and 5.6 as against 3.5 and 5.0 given by Cravath. As regards derivation the formulas are practically the same.

The foregoing figures are, as stated, given in trade bulletins for the use of illuminating engineers but there is considerable discrepancy in the figures correcting for reflection the illumination obtained by the point to point method and by the formula. To check these figures and obtain more definite data, as well as to interest the customers more in the subject of lighting, an illuminometer was built. A sketch of this is shown on Plate No.I.The essential parts are the standardized lamp, S; the mirror, M; and the screen, V. The latter is of the grease spot variety and the distance between S and V is varied by moving M which is mounted on a sliding carriage. The mirrors R enable the observer to view both sides of V and obtain the adjustment. At first glance trouble might be expected from light and shadows thrown by R, but these seem to neutralize and it is very seldom that there is any trouble noticeable from this cause. The box is lined with black velvet having a flap to protect the slot in which the carriage of M runs. Errors due to reflection and angle of incidence on the screen were determined by a calibration of the box. The standard lamps used were calibrated at the University of Utah and are of four and sixteen candle-power. Altogether the instrument seems to be more accurate than conditions governing the lighting, such

as voltage regulation, etc., and is therefore satisfactory for practical measurements.

In taking all measurements a sufficient number of observations were taken to obtain a good average value and all settings were triple checked. The candle-power of the standard was obtained by voltmeter readings and a calibration curve, and all values were corrected to 115 volts. Installations were selected which were fairly representative of the conditions which it was desired to investigate.

The following tabulations give the conditions and results of the various tests. Comparison is made with tests of reflex gas lamps taken by the Consolidated Gas Co. of New York in their office(Tests No. 11, 12, and 13). These are described in the January, 1910, number of the transactions, I.E.S.

Test No. I.

Walls	Light green.
Ceiling	Cream, 15 ft.
Width, inside wall fix.	23½ ft.
Wall fixtures	
Right side	7 ft. high, dark clothing.
Left side	Shelving, 9 ft.; varicolored boxes
Outlet spacing	20 ft.
Height of lamps	14 ft.
Lamps per outlet	One 500 watt, frosted.
Reflectors	G.E. monolux.
Floor	Bare wood, dark.
Candle feet	2.23
Lumens per watt	2.19

This store deals exclusively in gent's furnishings.

Test No. 2.

Walls	Light green.
Ceiling	Cream, I7 ft.
Width, inside fixtures	20 ft.
Wall fixtures	
Right side	Shelving, 8 ft.; varicolored boxes.
Left side	6½ ft. high, dark clothing.
Outlet spacing	24 ft.
Height of lamps	I0½ ft.
Lamps per outlet	Four I00 watts, frosted.
Reflectors	I-9 holophane.
Floor	Bare wood, dark.
Candle feet	I.82
Lumens per watt	2.I8

This store deals exclusively in gents furnishings.

Test No. 3.

Walls	Very light brown.
Ceiling	" " " , I4 ft.
Width, inside fixtures	23 ft.
Wall fixtures	
Right side	7 ft. high, dark clothing.
Left side	Shelving, 8 ft., varicolored boxes.
Outlet spacing	I7 ft.
Height of lamps	II ft.
Lamps per outlet	Four I00 watts, frosted.
Reflectors	E-9 holophane.
Floor	Brown linoleum.
Candle feet	2.4
Lumens per watt	I.8

This store deals exclusively in ladies'and gent's clothing. The test is fairly accurate but should have been more so. Readings were not takenat a sufficiently large number of positions.

Test No. 4.

Walls	Cream
Ceiling	Light brown, I5 ft.
Width, inside fixtures	I3½ ft.
Wall fixtures	
Right side	I0 ft. high, dark clothing.
Left side	Shelving, 8 ft., varicolored boxes.
Outlet spacing	I3 ft.
Height of lamps	I2 ft.
Lamps per outlet	Six 60 watts.
Reflectors	See remarks
Floor	Brown linoleum
Candle feet	2.40
Lumens per watt	I.I6

This store deals exclusively in gent's clothing. The lighting is furnished by G.E. clusters. These are fitted with a 24 inch white enamelled reflector which surrounds the receptacles outside a frosted, six compartment globe. Inside the globe the reflector is mirrored.

Test No. 5.

Walls	Very light brown.
Ceiling	Cream, 17 ft.
Width, inside fixtures	20½ ft.
Wall fixtures	
Right side	Both sides shelving, 8 ft.;
Left side	stocked with white goods.
Outlet spacing	20 ft.
Height of lamps	10½ ft.
Lamps per outlet	One 250 watt, clear.
Reflectors	Type D holophane, 12 inch.
Floor	Bare wood, dark.
Candle feet	1.55
Lumens per watt	2.54

This is a 5, 10, and 15 cent store.

Test No. 6.

Walls	White shoe boxes.
Ceiling	Cream, I8 ft.
Width	I2 ft.
Fixtures	Shelving to ceiling on both sides.
Outlet spacing	I5 ft.
Height of lamps	8½ ft.
Lamps per outlet	One I00 watt, frosted.
Reflectors	Type D holophane, 6 inch.
Floor	Bare wood, dark.
Candle feet	I.52
Lumens per watt	2.74

This store deals exclusively in shoes.

Test No. 7.

Walls	White shoe boxes.
Ceiling	Cream. I6 ft.
Width	22 ft.
Wall fixtures	Shelving stocked with shoe boxes.
Outlet spacing	I5 ft.
Height of lamps	II ft.
Lamps per outlet	Three 60 watt clear.
Reflectors	Type E-7 holophane.
Floor	Brown linoleum.
Candle feet	I.II
Lumens per watt	2.44

This store deals exclusively in shoes.

Test No. 8.

Walls	Light blue.
Ceiling	Cream and light blue, 16 ft.
Width, inside fixtures	14½ ft.
Wall fixtures	
Right side	Glass front, 8 ft.; stocked with black hats.
Left side	Varicolored boxes, 10 ft. high.
Outlet spacing	Rectangles, 12 ft. by 10½ ft.
Height of lamps	9 ft.
Lamps per outlet	One 100 watt, clear.
Reflectors	E-9 holophanes.
Floor	Brown linoleum.
Candle feet	2.09
Lumens per watt	1.80

This store deals exclusively in gent's furnishings. The values of candle feet and lumens per watt given were corrected to 125 volts, the voltage of the lamps. The observed values were 1.64 candle feet and 1.41 lumens per watt, at about 116 volts.

Test No. 9.

Walls	White.
Ceiling	White, 9ft.
Dimensions	33 by 53 ft.
Wall fixtures	Tables with dark clothing; also throughout room.
Outlet spacing	12 ft. square.
Height of lamps	7½ ft.
Lamps per outlet	One 100 watt frosted.
Reflectors	E-9 holophane.
Floor	Concrete
Candle feet	1.82
Lumens per watt	2.12

Basement of a department store containing chiefly workingmen's clothing.

Test No. I0.

Walls	Light bluish green.
Ceiling	Light bluish green, I3 ft.
Width inside fixtures	20½ ft.
Wall fixtures	Mahogany, 8½ ft. high, glass front. Carry silverware and glass.
Outlet spacing	Rectangles I5½ ft. by I2½ ft.
Height of lamps	I2 ft.
Lamps per outlet	Seven 40 watt tantalum.
Reflectors	Glass prism pendants.
Floor	White tile.
Candle feet	I.72
Lumens per watt	I.00

Jewelry store.

Test No. II.

Walls	Straw.
Ceiling	White, I2 ft.
Width	23 ft.
Fixtures	Gas stoves.
Outlet spacing	I3 ft.
Height of lamps	I0 ft.
Lamps per outlet	Four reflex gas.
Reflectors	Extensive holophanes.
Floor	Bare wood, dark matts.
Candle feet	4.64
Consumption	3.3 cu. ft.per hour per mantle.
Lumen-hours per cu. ft.	87.5

Test taken in the office of the Consolidated Gas Co. of New York.

Test No. I2.

Walls	Straw
Ceiling	White
Width	22 ft.
Fixtures	Desks
Outlet spacing	8 ft. arranged in rectangles.
Height of lamps	8½ ft.
Lamps per outlet	One reflex.
Reflectors	Extensive holophane.
Floor	Linoleum.
Candle feet	4.57
Consumption	3.2 cu. ft. per mantle per hour.
Lumen-hours per cu. ft.	92.I

Test taken in the office of the Consolidated Gas Co. of New York.

Test No. 13.

Walls	Straw
Ceiling	White, 10 ft.
Width	22 ft.
Fixtures	Desks
Outlet spacing	9 ft.
Height of lamps	8 ft.
Lamps per outlet	Four reflex.
Reflectors	Opal balls.
Floor	Linoleum
Candle feet	5.65
Consumption	3.5 cu. ft. per mantle per hour.
Lumen-hours per cu. ft.	79.4

Test taken in the office of the Consolidated Gas Co. of New York.

DISCUSSION OF TESTS

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In order to check the results obtained in the tests of illumination with the data furnished by the manufacturers of electric and gas lamps, the results obtained in test No. 7 are compared with those in No. II, the conditions being very similar as regards color values and reflectors. This comparison is in turn checked against a similar comparison of curves furnished by the manufacturers. The comparisons follow:

Test	Lumen-hours	Ratio
II	8750 per 100 cu. ft.(30" Plane)	3.58 to I.00
7	2440 " K.W.H. " "	

Reflex, ext. holophane, 17900 L-H. per 100 cu. ft.	2.82 to I.00
100 watt, " " , 6350 " " K.W.H.	

The difference in ratios is easily explained by the fact that the reflex lamps were lower than the tungstens in tests No. 7 and II and throw more light, relatively, below the 45 degree angle. Considering these facts the tests of gas and electric lighting under operating conditions show about the same relation to the respective figures furnished by the manufacturers. The tests in service, however, indicate a constant in lumens per watt of about 50% that given in the trade bulletins. Inasmuch as the lighting designed by the formulae given is satisfactory, the only practical result is to decrease the number of candle feet given in the table by about 50%. This is immaterial within itself but the absolute variation is considerable and is hard to explain. Numerous checks on methods and data show no error and almost the only conclusion left is that

the variation is caused by the computation of the constants given in the trade bulletins from the initial candle-power curves rather than from tests taken under operating conditions.

A comparison of the various results obtained indicates that the greatest efficiency can be gotten, as far as lighting alone is concerned, without bowl type reflectors. This is evidenced by tests 5 and 6 as compared with 7, although the lamps in No. 6 were considerably lower. The difference would likely be less if the lamps were the same height. Test No.4 indicates very clearly the effect of heavy frosting in reducing the efficiency of a lamp. This store is one of the best lighted in town but the lighting is costly because of the low efficiency. Test No. I shows results obtained from the 500 watt size of lamp. The combination of an art glass reflector and a large lamp gives a very satisfactory fixture for large interiors, and being very efficient must come into general use.

Tests under which general conditions were similar as regards decoration and coloring are Nos. I and 2; Nos. 3 and 4; Nos. 5,6,7,II,I2, and I3; and Nos. 8 and 9. Those similar reflectors are Nos. 3, 7, 8, and 9; Nos. 5 and 6; and Nos. II and I2. Comparing tests in which similar reflectors were used does not give satisfactory comparison of the reflecting values of different colored surfaces, but a paper presented before the Philadelphia section of the I.E.S. on Oct. 2I, I9I0, by F.H. Gilpin gives some very good comparisons which are here reproduced. These results show some variation due to the character of the reflecting surfaces but in the main the differences seem to be caused by the colors.

TABLE OF REFLECTION COEFFICIENTS

F.H. GILPIN

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Kind of Paper	Finish	Color	Efficiency of Incident Angle with Normal of					
			60°	45°	30°	15°	88°	Mean
Pulp tint	Matt (smooth)	White	56.0	61.5	58.2	56.5	54.6	57.3
Pulp tint	Matt (smooth)	Light buff	46.0	47.4	45.7	43.8	42.7	45.1
Pulp tint	Matt (smooth)	Lt. orange yel.	42.5	44.1	43.0	42.5	42.4	42.9
Silk fiber	Semi-gloss	Orange yellow	38.5	36.0	33.3	31.4	30.0	33.8
Silk fiber	Semi-gloss	French gray	37.6	32.2	25.6	22.6	21.0	26.0
Silk fiber	Semi-gloss	Lt. pea green	27.8	25.7	21.4	18.9	18.5	22.2
Silk fiber	Semi-gloss	Dk.pea green	23.5	18.6	14.4	11.2	9.3	15.4
Silk fiber	Semi-gloss	Light brown	16.8	14.6	11.7	10.9	10.3	12.9
Silk fiber	Semi-gloss	Light blue	15.5	13.0	10.0	9.2	8.1	11.2
Silk fiber	Semi-gloss	Cherry red	13.7	11.8	8.9	7.0	6.3	9.5
Imported stock	Fibrous	Tan	19.3	19.0	17.3	16.3	15.7	17.5
Imported stock	Fibrous	Light blue	13.5	13.4	12.0	11.0	10.2	12.0
Duplex	Rough	Light blue	12.7	12.0	10.5	9.1	8.2	10.5
Duplex	Rough	Cherry	6.6	6.4	6.2	6.0	5.7	6.2
Plain	Rough	Yellow buff	31.4	34.3	35.6	35.0	35.0	34.4
Plain	Rough	Lt. pea green	21.5	20.4	19.8	18.8	18.2	19.7
Plain	Rough	Dk. pea green	13.4	12.7	11.3	10.7	8.9	11.6
Plain	Rough	Deep red	7.3	7.0	5.9	5.3	4.9	6.1
Varnished Tile	Glossy	Cream	66.3	71.1	73.1	71.8	70.8	70.6
Imported	Embossed Gloss	Gilt	54.0	49.3	43.7	37.7	27.0	41.7
White blotter			72.7	80.0	73.9	72.9	71.1	74.0

The tests from which these figures were obtained were all taken on papers. Most of the places upon which tests of illumination were taken had tinted walls and ceiling.

GAS LIGHTING

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Thus far attention has been paid chiefly to electric lighting, but the developments in gas lighting within the last few years have been quite as rapid as has been the case with electric. The introduction of the vertical mantle and, later, of the inverted mantle was analogous to that of the metal filament lamps and was as important to the gas industry as was the latter to the electric. For this reason very little attention will be paid to any other form of gas lighting.

The design of a system of gas lighting differs considerably from electric inasmuch as pressure regulation and depreciation are relatively much more important factors. Curves given by Norman Macbeth in the Nov., 1910, number of the Transactions, I.E.S., one of which is reproduced on Plate 2, show very clearly the variation of flux with consumption under proper conditions, although no comparison is made under improper conditions such as are introduced by pressure fluctuations with a constant adjustment. Plate 3 shows the initial distribution curves of a 100 watt tungsten and a reflex mantle, each equipped with the extensive holophane reflector. The total light flux given by each, with the gas burner properly adjusted at 20 tenths, is about the same, but a slight variation of pressure or depreciation of the mantle varies this considerably in favor of the tungsten. The effect of pressure variation may readily be seen when it is considered that if, after adjustment, the pressure is increased, the air intake is not sufficient to burn the gas within the mantle; while if the pressure is decreased, the supply of gas is insufficient. Under either condition the efficiency

of the mantle is reduced. Tests in Salt lake City show a pressure variation of from 25 to 45 tenths and under these conditions an inverted mantle and a 60 watt tungsten are found to be about equivalent in light giving power. Therefore, to determine the number of mantles necessary for a given installation the second formula may be used by the substitution of 250, the effective lumens per 60 watt lamp, in the denominator. The formula then becomes

$$\text{No. Mantles} = \frac{\text{Area X Candle Feet}}{250}$$

This formula may be used in connection with the tables of satisfactory illumination given and will be found to produce good results.

In order to compare the costs of coal gas and electric lighting, tests were taken on sixty mantles in various installations and at various times during the day. The average consumption shown was 5.35 cu. ft. per mantle per hour, or corrected to sea level, about 4.55 cu. ft.. Taking the latter figure with gas at $1.00 per M gives a cost of .45¢ per hour as against .60¢ in the case of electric at 10¢ per K.W.H.. At Salt Lake City a comparison of monthly bills shows a ratio of electric to gas, for equivalent lighting, of about 6 to 5 which checks very well with the foregoing since tests of tungstens show them to run a little above rated wattage. The maintenance costs in each case are about the same and gas lost through pilots is included in the monthly bills. This item averages perhaps 5%.

The chief arguments for the two systems of lighting are, for the gas; reliability of service, less cost, heat in winter; and for the electric;convenience, cleanliness, more hygienic conditions, and absence of heat. It is probable that the upkeep cost averages

about the same in each case. Altogether the preponderance of either system, other conditions being equal, is usually the result of strenuous efforts on the part of the operating companies in the case of competition, or the attitude of the one company if both utilities are controlled in common.

As far as other methods of lighting are concerned, gasoline is the only serious competitor of gas and electricity. This is too dangerous to appeal to the average man and gives little trouble to the operating companies, although in cost it compares with electricity at 7¢ per K.W.H.

SPECIAL CASES OF LIGHTING

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The foregoing discussion as given is applicable to the general lighting of interiors, but there are special cases which demand especial treatment. The chief of these is window lighting and this is in fact almost as important both to the central station and to the merchant as the general lighting.

In the lighting of windows it is possible to approach more nearly to daylight distribution than under any other conditions. The principle utilized may be illustrated by the distinctness of the eastern landscape in the late afternoon of a clear day; and the conditions to be avoided by the indistinctness of the western landscape at the same hour. Formerly it was considered good practice to install tungstens with holophanes in the ceiling of the window, but the disadvantages of such an arrangement were quickly seen and the development of a line of silvered glass reflectors for use with tungstens, and of the linolite, have made it possible to place the lamps well to the front and conceal all direct rays from the eye. This organ is thus permitted to operate at its highest efficiency, which result is fully as effective as an increase of light. Another advantage is that the light itself does not detract from the goods.

There are different types of the mirror reflectors, but two of these will fill almost all conditions. These are the helmet for high ceilings and shallow windows, and the scoop for windows having a height about equal to the depth. The linolite is also well adapted to the latter class of windows. The standard of lighting required for windows is much higher than for general lighting and varies with the class of goods displayed. The best method of

computation for the scoop reflector and linolite is to assume as the plane of illumination the diagonal plane extending from the lower front corner to the upper rear corner of the window; for the helmet, a plane extending from the lower front corner to a line on the rear wall two-thirds of the way from floor to ceiling. Practically 80% of the light thrown out falls on these planes and if the efficiency of the tungsten lamp is taken at 6.5 lumens per watt the formula

$$\text{Watts} = \frac{\text{Area} \times \text{Candle-feet}}{5.2}$$

gives very good results.

This formula indicates that window lighting is more efficient than general interior lighting and this is true as there is practically no reflected light from the walls effective on the goods displayed, all light coming directly from the source.

Decorative lighting is another special case which demands attention. This form of lighting is used in many different connections but as a general rule it is found most economical to so arrange the installation that the main lighting comes from highly efficient units, while the decorative lighting is furnished by lamps of small size arranged as desired. It is usually rather expensive to enclose large lamps within art glass shades and depend upon them thus arranged for general lighting effects. Very often where lamps are grouped,as over a soda fountain, it is possible to use tungsten sign lamps with a transformer, but where the outlets are scattered it is preferable to use carbon lamps of small size and standard voltage.

Two forms of lighting which are very closely related

and which are governed by the same principles are individual desk and general office or drafting room lighting. The objects to be attained are a maximum illumination upon the subject of the eye's attention and a general mild illumination without sharp cross lights or contrasts to annoy the eye. The most accepted form of general office lighting is by the use of units equipped with frosted lamps and intensive or focussing reflectors hung at some height above the tables and in such a position as to throw the reflection or "glare" away from the eye. The latter feature is one of the most fruitful sources of trouble which exists where the eye is compelled to concentrate considerable attention to work on paper. For single desks the best form of lighting is given by a lamp equipped with focusing reflector and hung about seven feet above the left shoulder of the party using the desk. These methods are not entirely satisfactory but could hardly be improved upon except that a more opaque reflector might be used which would permit less light to fall upon the walls and, in the case of general office lighting, enter directly the eyes of parties some distance away. A very good form of lighting for reading is given by a stand lamp with a green or amber shade which screens direct rays and so darkens the room as to render the eye very sensitive to the object of its attention.

An important branch of lighting work, but one which has been very much neglected, is that pertaining to residences. Here old methods are still prevalent. The common method of lighting is by the use of bare or poorly shaded carbon lamps placed in low hanging fixtures, and now that the promises of a stronger tungsten lamp seem in a fair way to be fulfilled, the fight for an improvement of conditions will be much harder than is at present the case.

In studying the subject of residence lighting the same general conditions governing other forms of interior lighting are found. For such rooms as the parlor, bedrooms, kitchen, etc., requiring general lighting, a lamp hung high with a suitable reflector is best, while for the dining room an art glass dome, preferably amber, hung at such a height as to protect the eyes of those seated at the table and fitted with a holophane reflector over the lamp will be found servicable. For the library a combination of general lighting and stand lamp will perhaps be found best suited to the conditions.

There are, of course, many other special forms of interior lighting but they need not be discussed in detail. The chief object to be attained is satisfactory illumination without such lighting and sharp contrasts as are irritating to the eye. Each case requires special study, both as to conditions of lighting and the desires of the customer, but the principles outlined are generally applicable and if followed will give very good results as measured by present day standards.

STREET LIGHTING

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Very different from interior lighting in many of its conditions is the problem of street lighting. In the past the prevailing custom has been to employ high power units but the many faults of this system, such as the high intrinsic brilliancy of the source, wide variation in the values of illumination, and deep contrasts have left much to be desired. In common with interior lighting there have in recent years been many developments in the methods and apparatus employed in street lighting. The flame arc, luminous arc, and tungsten lamp are crowding out the old carbon arc. At present there seems to be a decided tendency towards the use of ornamental tungsten lighting, although the other units, especially the flame arc, are being used to a considerable extent. Just what the outcome will be is hard to forecast. For commercial districts the flame arc possesses many advantages because of the amount of light desired, but for residence districts, while conditions are much bettered, the old objections still remain. For this class the tungsten would seem better adapted because of the distribution made possible by the fact that for the same cost of operation, and probably for very little greater initial cost, a much larger number of units can be employed. Altogether the matter is very unsettled but rapid progress is being made and succeeding years should see much improvement in conditions.

CONCLUSION

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With the development of the commercial idea the progressive element among central station men has come to realize that the public is to be courted, not defied, and that in the courting lies wonderful possibilities for the future of the industry. The creation of public service commissions is doing much to render the business a safe investment; this with the betterment of lighting conditions resultant from the progress now being made should give an impetus to the industry such as has never before been known. It is because of the fact that so much of the development, past and prospective, is dependent upon the illuminating engineer that the profession has assumed so much prominence during the last few years, and during the succeeding years the advance must be much more marked. The science is yet in its infancy and the possibilities are manifold both for physical and practical development of the subject.

DESCRIPTION OF PHOTOGRAPHS

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The photographs shown are mainly of installations designed by the writer or upon which tests were taken. Following is a brief description of each. For names see list of plates.

Plate No.

5A- Window lighting with scoop reflectors.

5B- Lighting from one fixture having ten I00 watt tungstens and two fixtures having four I00 watts each. The tungstens are equipped with F-9 holophanes and two 5 mantle gas arcs are provided for emergency. The photograph illustrates the effect of a light floor.

5C- Lighting from tungstens and type E holophanes. The units are placed too low and do not light the ceiling.

6- See test No. I0

7A- " " " I

7B- " " " 4

7C- " " " 2

8- Light from four light fixtures equipped with 60 watt tungstens and type E holophanes Lamps I2 feet high, outlets I8 feet apart.

9- Lighting from I50 watt tungstens and I-I3 holophanes. Lamps II high and II feet apart.

I0- Same window as shown in No. 5A.

II-Light from four I00 watt tungstens and E-9 holophanes per outlet. Lamps I0 feet high, outlets I8 feet rectangles.

I2- All outlets equipped with 40 watt tungstens and E-5 holophanes except one having gas arc for emergency Fountain lighting with 5 watt tungstens and transformer.

I3- Arrangement very similar to No. II.

I4- Lighting from I00 watt tungstens and F-9 holophanes.

I5- Lighting from 2 light fixtures equipped with I00 watt tungstens and E-9 holophanes. This could have been accomplished more satisfactorily by the use of larger lamps.

LIST OF PLATES

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Plate No.

I- Sketch of illuminometer.

2- Curves of reflex mantle, by Macbeth.

3- Distribution curves of I00 watt tungsten and reflex mantle, each equipped with extensive holophane reflector.

4- Calibration curve of illuminometer.

5A- Mullett Clothing Co., Salt Lake City; windows.

5B- Stickney Cigar store, Salt Lake City.

5C- Hemenway & Moser Cigar Co., Ogden.

6A- Lewis Jewelry Co., Ogden; interior. (Test No. I0)

6B & C- Same,illuminated show cases.

7A- F. M. Nye Co., Ogden. (Test No. I)

7B- S. H. Browne Co., Ogden, (Test No. 4)

7C- A. Kuhn & Bro., Ogden. (Test No. 2)

8- 5, I0, & I5 Cent Store, Salt Lake City.

9- Mehesy's fur store, Salt Lake City.

I0- Mullett Clothing Co., Salt Lake City; windows.

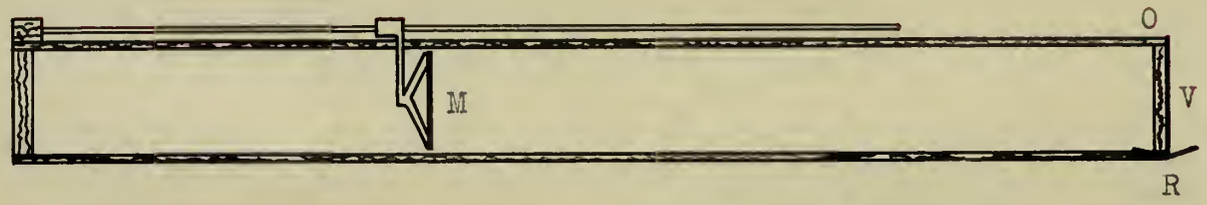
II- Same , interior.

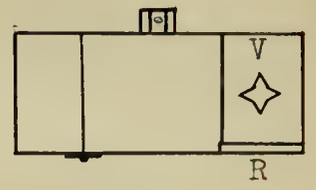
I2- Van Dyke Drug Co., Salt Lake City.

I3- Shay's cafeteria, Salt Lake City.

I4- United Cigar Stores Co., store No. 2, Salt Lake City.

I5- Palm Garden Saloon, Salt Lake City.





Orifice at O for observing lower
half of mirror R.

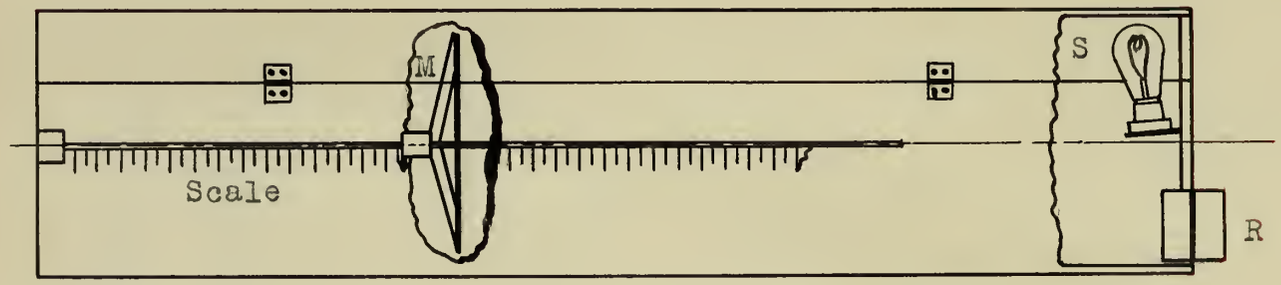


Plate No. I

Sketch of Illuminometer

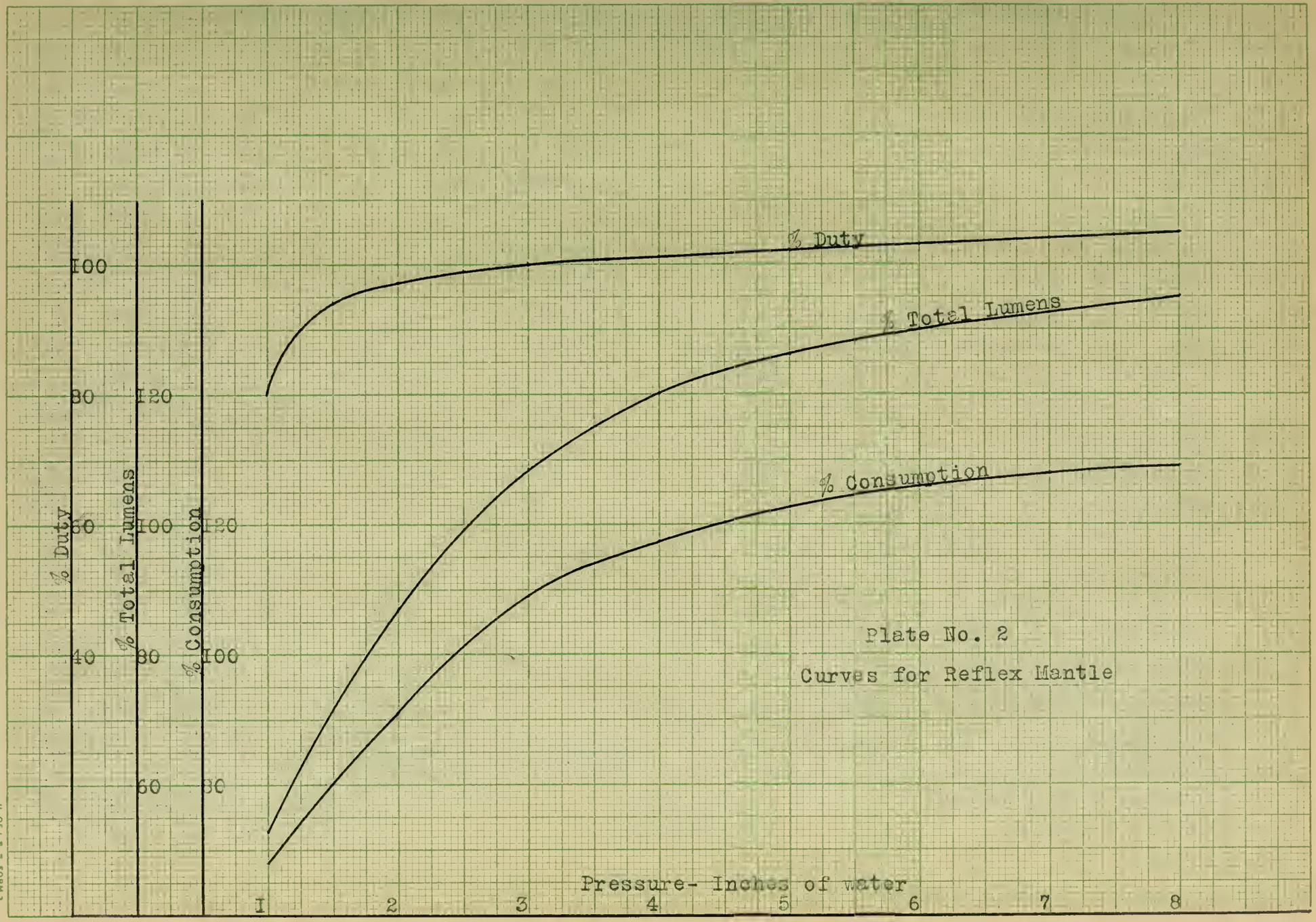


Plate No. 2

Curves for Reflex Mantle

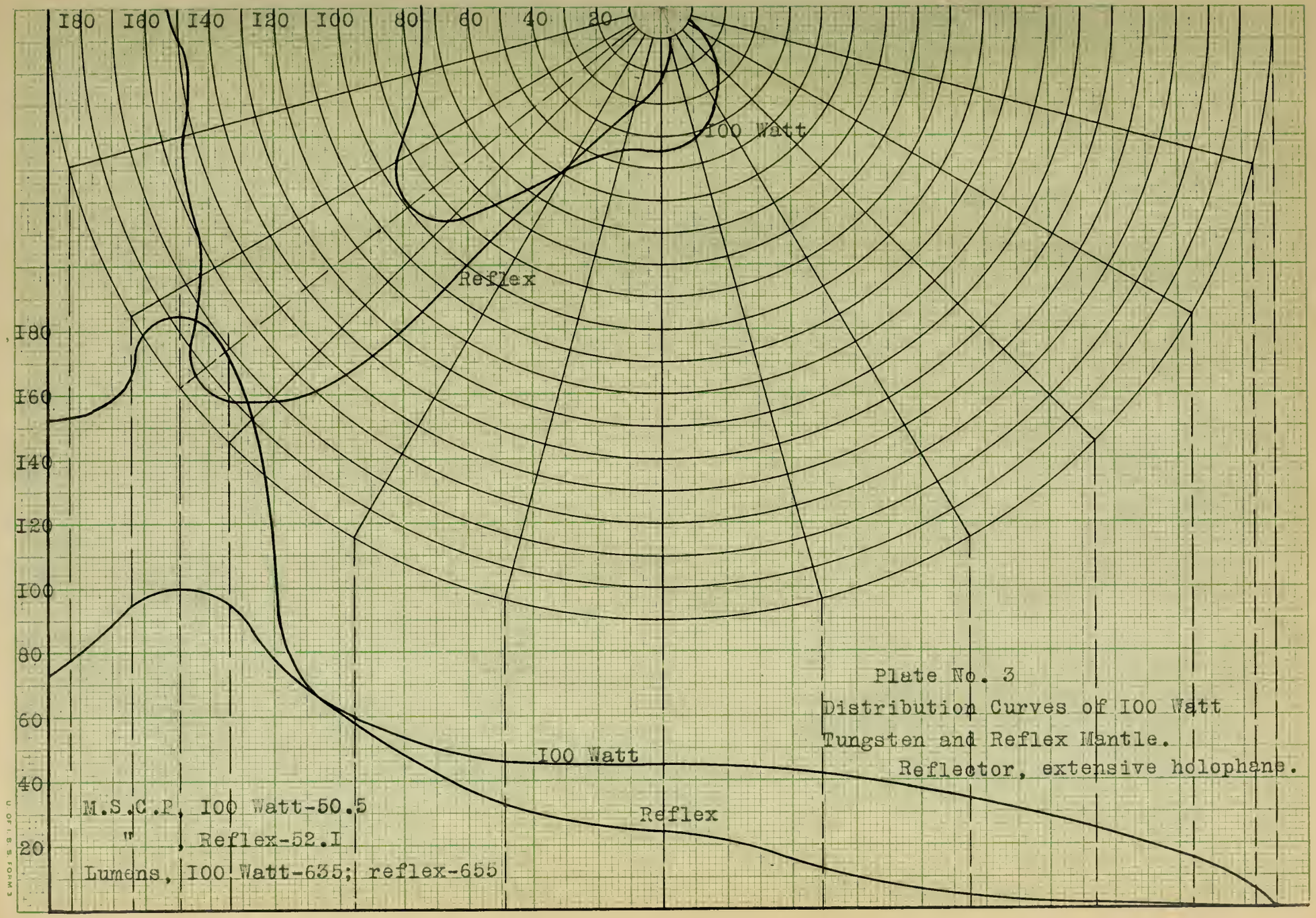


Plate No. 3
Distribution Curves of 100 Watt
Tungsten and Reflex Mantle.
Reflector, extensive holophane.

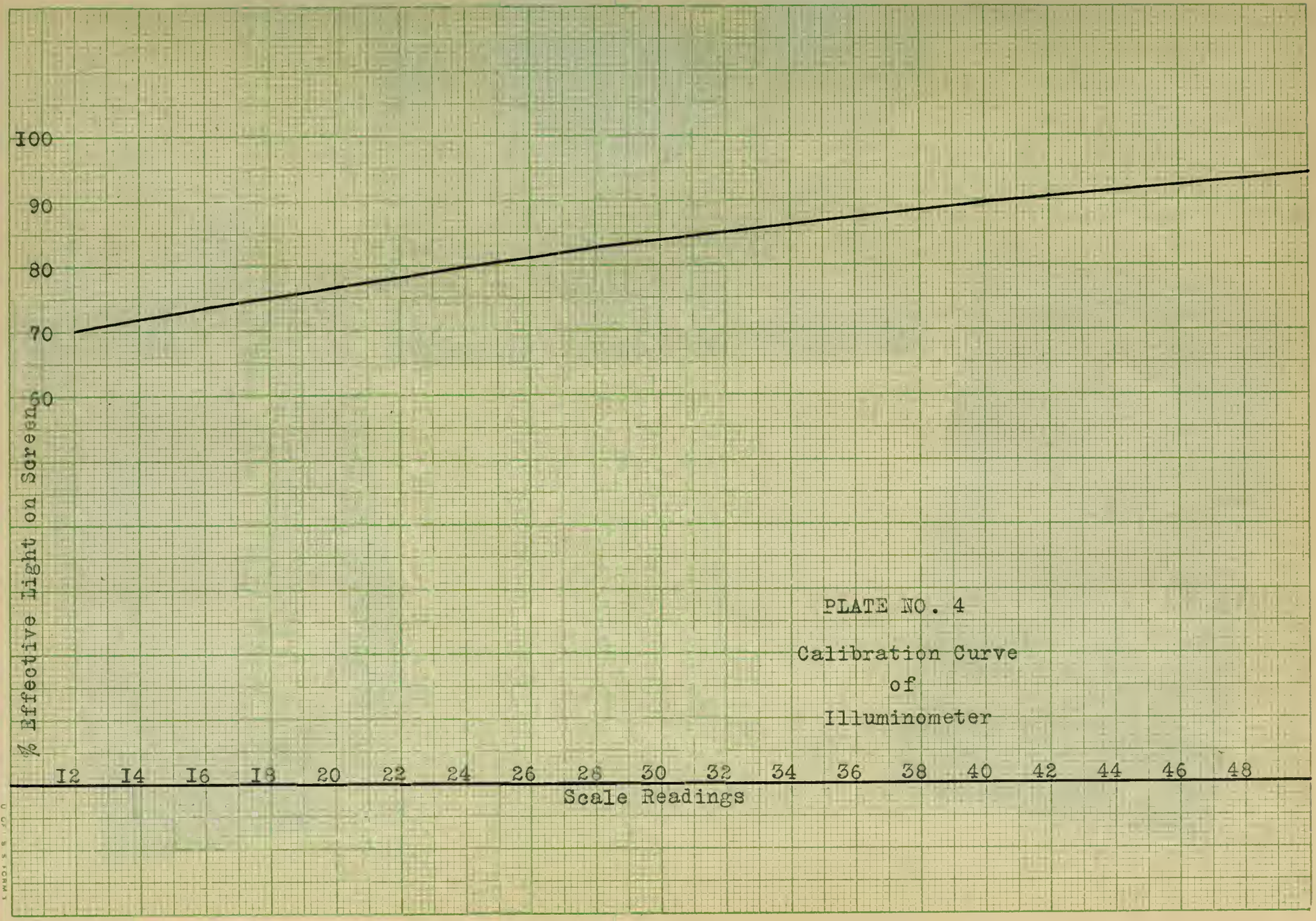


PLATE NO. 4

Calibration Curve

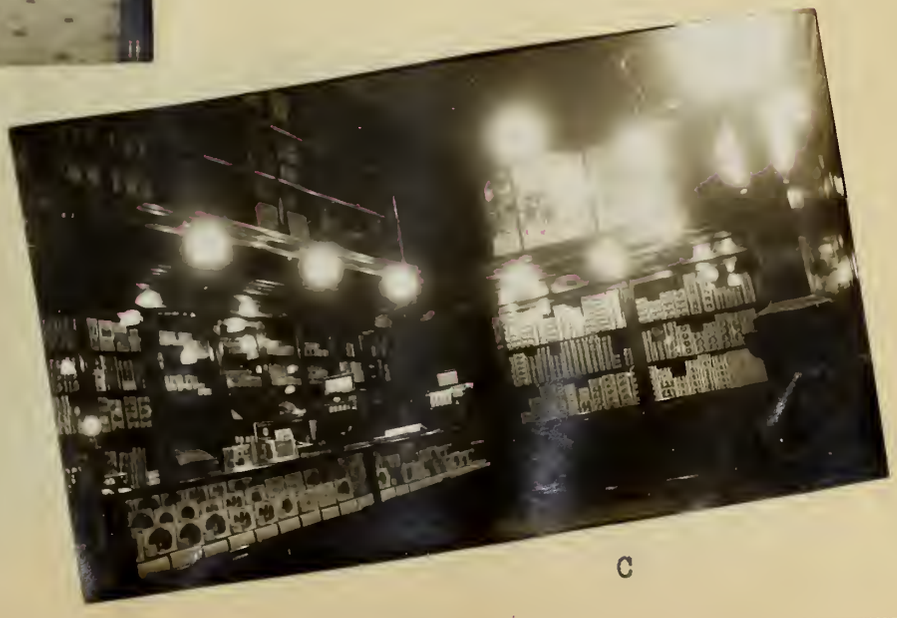
of

Illuminometer

A

B

Plate No. 5



C

A

Plate No. 6

B

C

A

Plate No. 7

B

C

Plate No. 8

Plate No. 9

Plate No. IO

Plate No. II

Plate No. I2

Plate No. I3

Plate No. I4

Plate No. I5